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Quantitative Analysis of MRI Data in Dementia Research

Introduction

Dementia's progressive nature necessitates understanding its impact on brain structures. This report examines changes in brain volume associated with dementia, analyzing MRI data to investigate these changes across multiple visits. this report seeks to answer the research question:

1.How does dementia status affect normalized whole brain volume(nWBV) across different visits?

2.Does the change in estimated total intracranial volume (eTIV) across visits vary by dementia status?

Data Preparation

Rows with any missing data(in the SES and MMSE columns), were excluded to avoid bias in the results.

From the initial set of variables, I focused on those most relevant to the research questions:

- **Group**: The between-subjects factor served as dementia status(Demented, Nondemented, Converted).

- **Visit**: The within-subjects factor, capturing the changes in MRI measures across different time points.

- **nWBV and eTIV**: Dependent variables representing brain volume measures.
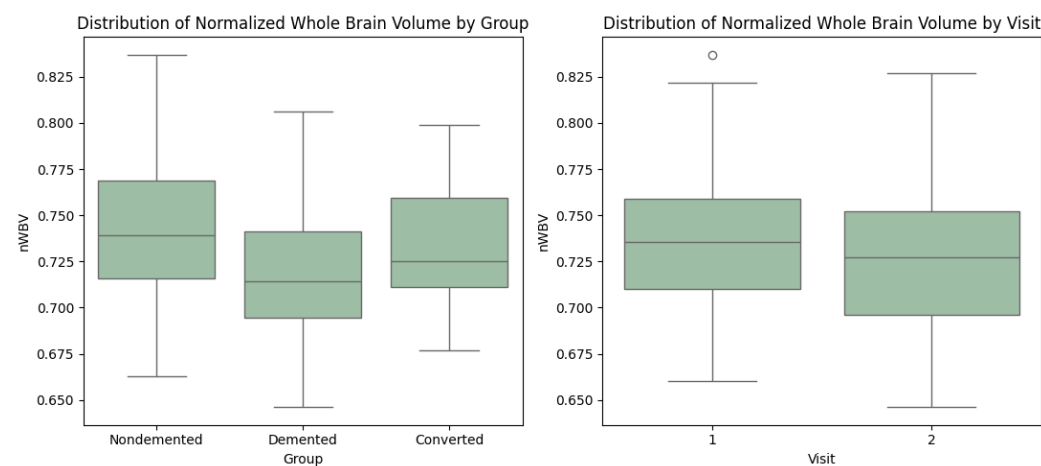
Examination of interested variables

Figure-1 Distribution of normalized whole brain volume by group/visit

Figure 1 displays differing nWBV across dementia statuses: 'Converted' individuals exhibit the lowest nWBV, while 'Nondemented' subjects show greater variance. The decline in nWBV from the first to the second visit across all groups suggests an expected reduction over time.

Figure 2 shows eTIV distributions with outliers, particularly in the 'Nondemented' group, and similar median values among groups, indicating consistent intracranial volumes across dementia statuses. Over visits, eTIV remains stable, albeit with greater variability at the second visit.

In Figure-3, the left graph shows a decline in nWBV across all dementia groups, most notably in the 'Converted' group, while the right graph states that eTIV remains consistent over time for all groups. These patterns underscore the importance of researching how dementia influences brain volume changes over time.
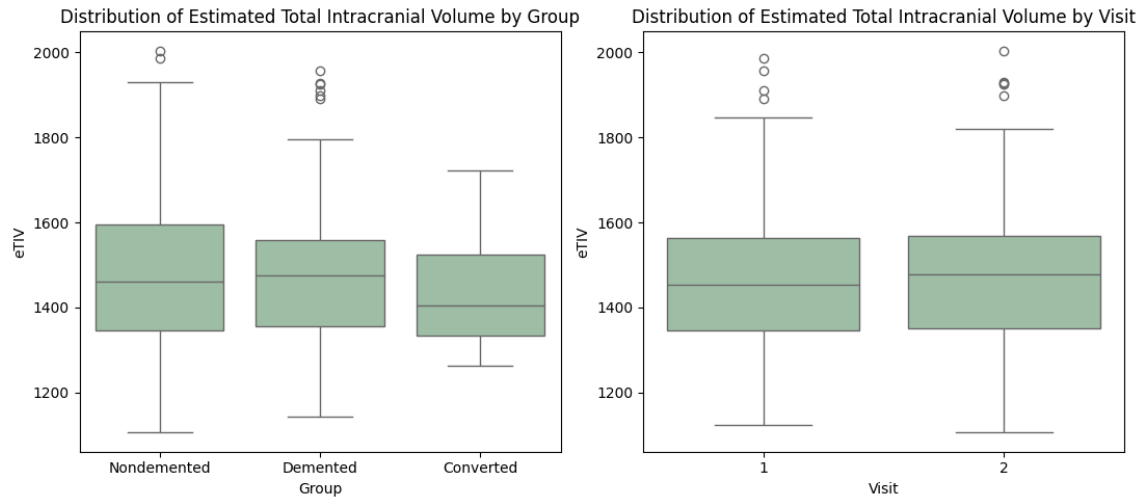
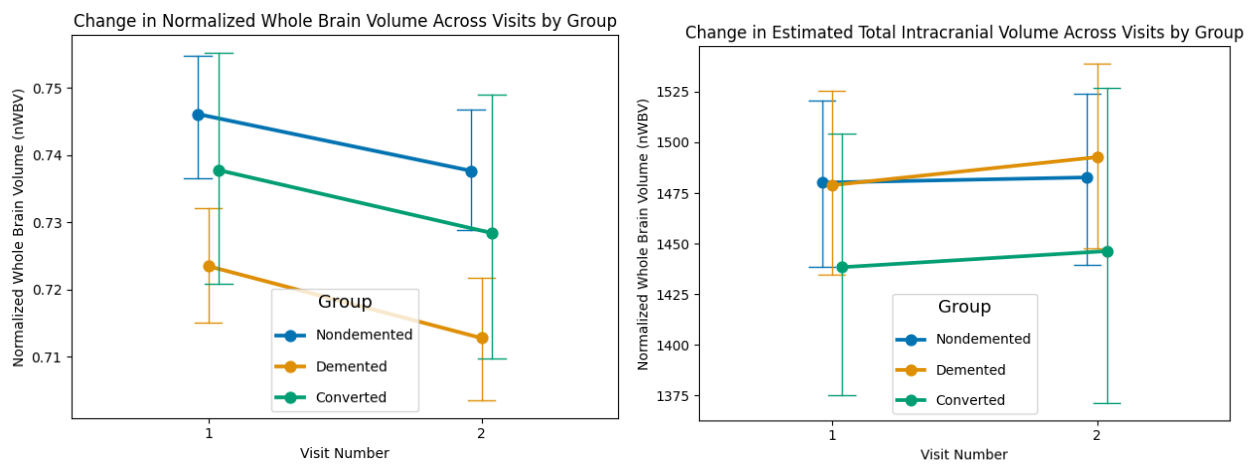Figure-2 Distribution of estimated total intracranial volume by group/visit

Figure-3 point plots of dependent variables across visits by groups

Mix-effects ANOVA(question 1: normalized whole brain volume)

Assumption Testing

Table 1: Assumptions Test for mixed-effects ANOVA(normalized whole brain volume)

Test	Statistics	P-value	Interpretation
Shapiro-Wilk	W = 0.989 (Nondemented)	p = 0.317	Normality assumed
Shapiro-Wilk	W = 0.987 (Demented)	p = 0.366	Normality assumed
Shapiro-Wilk	W = 0.958 (Converted)	p = 0.358	Normality assumed
Levene's Test	W = 0.489	p = 0.614	Homogeneity of variances assumed
Sphericity Test	-	-	Sphericity assumed

1. **Shapiro-Wilk Test**: The p-values for all groups exceed 0.05, suggesting that the data distribution for each dementia status group (Nondemented, Demented, Converted) adheres to normality.

2. **Levene's Test**: With a p-value of 0.614, the result concludes that the variance across groups is consistent, satisfying the assumption of homogeneity of variances.

3. **Sphericity Test**: The initial result admits sphericity is met. However, the absence of statistics and a p-value implies that it should consider using corrections for sphericity in ANOVA as a precaution.

ANOVA Results and Interpretation

Table-2 ANOVA Results(normalized whole brain volume)

Source	Sum of Squares	df1	df2	Mean Square	F-value	p-value	Partial Eta Squared	Epsilon
Group	0.033	2	134	0.017	6.384	0.002*	0.087	-
Visit	0.006	1	134	0.006	89.376	< 0.001*	0.400	1.0
Interaction	0.000	2	134	0.000	1.630	0.200	0.024	-

Note: P-values less than 0.001 are reported as "< 0.001" to indicate significance beyond the threshold of 0.001.

1. **Group Effect(p = 0.002)**: Significant differences exist between groups, explaining about 8.7% of the variance in the dependent variable.

2. **Visit Effect(p < 0.001)**: Changes across visits are significant, accounting for 40% of the variance, indicating a strong time effect.

3. **Interaction Effect(p = 0.200)**: The group and visit interaction is not significant, with a minor effect size (2.4%), suggesting no differential change across groups over time.

Epsilon for 'Visit' is 1.0, indicating no need for sphericity correction. The analysis underscores significant main effects of 'Group' and 'Visit' without a notable interaction between them.

Post-hoc testing Results and Interpretation

Table-3 Post-hoc testing results(normalized whole brain volume)

Contrast	Group A	Group B	T-value	p-Value (Uncorrected)	p-Value (Corrected)	Hedges' g
0	Converted	Demented	2.058	0.047	0.07	0.447
1	Converted	Nondemented	-1.142	0.260	0.26	-0.222
2	Demented	Nondemented	-5.195	< 0.001	< 0.001	-0.646

1. **Converted vs. Demented**: **T-value**: 2.058 indicates a moderate difference. **p-Value**: 0.047 before correction, 0.07 after, suggesting a marginal significance that weakens after adjustment. **Hedges' g**: 0.447 shows a moderate effect size.

2. **Converted vs. Nondemented**: **T-value**: -1.142 points to a small difference. **p-Value**: 0.260 before and after correction, indicating no significant difference. **Hedges' g**: -0.222, a small effect size.

3. **Demented vs. Nondemented**: **T-value**: -5.195 suggests a substantial difference. **p-Value**: <0.001 both before and after correction, indicating a strong significance. **Hedges' g**: -0.646, a large effect size.

The analysis shows a notable difference between the Demented and Nondemented groups, with less pronounced differences involving the Converted group.

Mix-effects ANOVA(question 2: estimated total intracranial volume)

Assumption Testing

Table 4: Assumptions Test for mixed-effects ANOVA(estimated total intracranial volume)

Test	Statistics	P-value	Interpretation
Shapiro-Wilk	W = 0.973 (Nondemented)	0.006	Normality violated
Shapiro-Wilk	W = 0.959 (Demented)	0.002	Normality violated
Shapiro-Wilk	W = 0.918 (Converted)	0.041	Normality violated
Levene's Test	W = 1.319	0.269	Homogeneity of variances assumed
Sphericity Test	-	-	Sphericity assumed

- **Shapiro-Wilk Test**: Shows a violation of normality for all groups, with p-values less than 0.05.

- **Levene's Test**: Indicates that variances are homogeneous across groups(p-value is greater than 0.05).

- **Sphericity Test**: Assumes sphericity, though specific statistics are not provided from initial test results.

ANOVA Results and Interpretation

Table-5 ANOVA Results(estimated total intracranial volume)

Source	Sum of Squares	DF1	DF2	Mean Square	F-value	p-Value	Partial Eta Squared	Epsilon
Group	38580.795	2	134	19290.398	0.306	0.737	0.005	-
Visit	5073.142	1	134	5073.142	8.139	0.005	0.057	1.0
Interaction	953.089	2	134	476.545	0.765	0.468	0.011	-

- **Group Effect**: The Group factor shows an F-value of 0.306 with a p-value of 0.737, indicating that the differences between groups are not statistically significant. $np^2 = 0.005$ suggests a small effect size.

- **Visit Effect**: The Visit factor has an F-value of 8.139 and a significant p-value of 0.005, indicating a significant effect of time or visit on the dependent variable. $np^2 = 0.057$ suggests a moderate effect.

- **Interaction Effect**: The interaction between Group and Visit yields an F-value of 0.765 with a p-value of 0.468, stating no significant interaction. The partial eta squared of 0.011 indicates a small effect size.

Epsilon values for the Visit effect, is reported as 1.0, indicating no sphericity violation.

In summary, while the Visit factor shows a significant effect, the Group factor and the interaction do not significantly affect the dependent variable, suggesting that changes observed are primarily related to the passage of time rather than group differences or their interaction.

Post-hoc testing Results and Interpretation

Table-6 Post-hoc testing results(estimated total intracranial volume)

Contrast	Group A	Group B	T-value	p-Value (Uncorrected)	p-Value (Corrected)	Hedges' g
0	Converted	Demented	-1.375	0.176	0.321	-0.258
1	Converted	Nondemented	-1.262	0.214	0.321	-0.220
2	Demented	Nondemented	0.191	0.849	0.849	0.024

- The post-hoc comparisons between the groups for eTIV are not statistically significant, as indicated by the corrected p-values exceeding 0.05.

- Effect sizes (Hedges' g) are small, showing minimal practical differences between the groups.

- The closest to significance is the contrast between the Converted and Demented groups, but the correction for multiple tests weakens this finding.

Conclusion: The ANOVA analyses revealed no significant group differences in intracranial volume (eTIV) but did indicate a time effect on brain volume (nWBV), with no interaction between group and visit. These results highlight the significance of temporal changes in brain volume across all dementia stages.
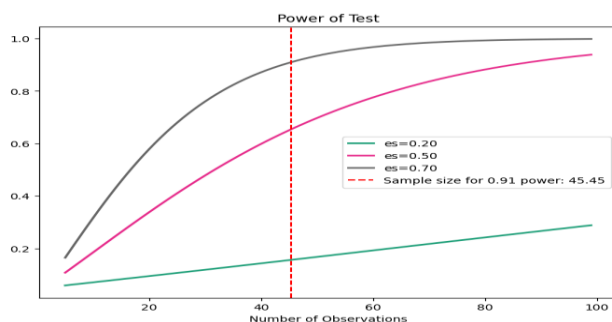

Power test: The power analysis graph(figure-5) and the required sample size for achieving a power of 0.91 is about 45.45.

The power analysis suggests that with an effect size of 0.70, a sample size of about 45 to 46 participants is needed to have a 91% chance of detecting a true effect in the population (power = 0.91).

Figure-5 statistical power plot